1990 NASA AUTHORIZATION

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BEFORE THE

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AVIATION AND MATERIALS

OF THE

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SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

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1990 NASA AUTHORIZATION

WEDNESDAY, APRIL 26, 1989

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS,
Washington, D. C.

The subcommittee met at 2:04 p.m. in Room 2325 of the Rayburn House Office Building, the Honorable Tim Valentine, chairman of the subcommittee, presiding.

Present: Representatives Valentine, Lewis, Campbell and Rohrabacher.

Mr. VALENTINE. Welcome, ladies and gentlemen. We will get started.

Today our subcommittee will consider NASA's fiscal year 1990 budget request for aeronautics, sometimes referred to as the small "a" in NASA.

Aeronautics, as viewed by this committee, has come to include two of NASA's budget line items: Aeronautical Research and Technology; and Transatmospheric Research and Technology, the latter item, also known as the Aero Space Plane program.

The Aero Space Plane, as most people know, has been the subject of intense discussions lately within the Administration. We plan to hold a joint hearing with the Armed Services Subcommittee on R&D to examine the progress in that program as well as options for the future.

Today we will be concentrating on the Aeronautical R&D line. This year, for the first time in many years, NASA proposed a budget containing some modest real growth above the level that has generally prevailed throughout this decade. In my opinion, this is a long overdue step because the foreign challenge to our aviation industry, which is one of the few remaining winners, has been mounting for some time now.

So, I am gratified to see that the Administration is finally taking some action. The task for us in the Congress will be to find a way to accommodate this growth at a time when the concerns about the overall budget are more important than ever. Investments in aeronautical research have been a good buy for the American taxpayer because, unlike most other Government expenditures, they return many times their original amount to the economy in the form of jobs and exportable products.

Our first witness today is one who we believe shares these sentiments. Dr. Ballhaus recently returned to the Ames Research

Center after one year as Acting Associate Administrator for Aeronautics and Space Technology at NASA headquarters.

Dr. Ballhaus, we welcome you here today and look forward to working with you and your successor, Dr. Rosen, as we develop legislation to authorize the NASA aeronautics program for the coming year.

I recognize my good friend, the ranking Republican member of the subcommittee, Mr. Lewis.

Mr. LEWIS. Thank you, Mr. Chairman.

Welcome, Dr. Ballhaus. It is good to see you. I am pleased to see the President's budget request for NASA aeronautics research is above last year's appropriations. In fact, the $462 million for research and technology represents a 14 percent increase. Most of the increase is for program growth rather than new starts.

I am delighted to see the support for ongoing research. This is a management philosophy that will insure the research program will produce the maximum results over the long term.

The transatmospheric research program, primarily the aerospace plane, budget request is up 45 percent to $127 million. This is a projected increase, as the NASA program moves toward completion.

On the other hand, the Department of Defense has not lived up to their funding agreement and has not requested sufficient funds for fiscal year 1990. The long-term negative impact of this shortsighted action may be enormous. The new technologies that would enable both our military and civil industries to be leaders could well be jeopardized.

I do not know what all of the available options are at this time. However, I do know that the battle to save NASP is not over. I am drafting legislation containing authorization language to continue the NASP program and it should be ready by the end of this week for the subcommittee. I hope today's witnesses will be able to shed some new light on these problems and suggest solutions.

Thank you, Mr. Chairman.

Mr. VALENTINE. Thank you, sir.

Mr. Campbell?

Mr. CAMPBELL. Thank you, Mr. Chairman.

Just a word of welcome to my friend and constituent and colleague, Dr. Ballhaus, and to say that it has been a real pleasure to visit Ames under your acting replacement and that I want to be a real resource and facilitate, if there is anything that I can do in, promoting what I think is one of the premier research facilities in the United States. It is just a shame you cannot be paid anymore for the amount that you contribute.

Thank you, Mr. Chairman.

Mr. VALENTINE. Mr. Rohrabacher?

Mr. ROHRABACHER. I am very happy that we are discussing the National Aerospace Plane today and the future of the National Aerospace Plane. I see that as a technology that is absolutely vital to our country's future.

And I am greatly disturbed by what we see happening with the budget of the Defense Department in terms of their part of the development of the National Aerospace Plane, and I am looking forward to speaking with you folks today about your feelings on what

that will mean to the future of the project and your analysis as to what our potential, I won't say adversaries, but competitors might be doing in the area of national aerospace plane research in Japan and other places.

So, again I want to commend the chairman for calling this hearing and focusing our attention on the subject, and I am looking forward to our further discussion.

Mr. VALENTINE. Thank you, sir.

Doctor, your prepared statement will appear in the record as you have presented it to us, and we are happy to hear from you at this time by way of summary or otherwise, as you would prefer to proceed. Welcome.

STATEMENT OF WILLIAM F. BALLHAUS, JR. DIRECTOR, AMES RESEARCH CENTER, NATIONAL AERONAUTICS AND, SPACE ADMINISTRATION; ACCOMPANIED BY CECIL ROSEN, DIRECTOR OF AERONAUTICS, OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY; AND EDMUND SANCHEZ, DIRECTOR OF OFFICE OF RESOURCES AND MANAGEMENT SYSTEMS

Dr. BALLHAUS. Thank you, members of the subcommittee, for your comments. I am pleased to present the fiscal year 1990 NASA aeronautics research and technology program.

Before I begin, I would like to introduce my two colleagues at the table. On my left is Mr. Cecil Rosen, director of aeronautics in the office of aeronautics and space technology for NASA. And on my right is Mr. Edmund Sanchez, director of our resources and management systems office.

Aeronautics has been important to the United States ever since the Wright brothers first flew at Kitty Hawk, which is actually where it all began, in your native State, Mr. Chairman. This importance was recognized in 1915 when the NACA was chartered to direct and conduct research and experiments in aeronautics. This research was vital to the emerging U.S. aviation industry and the national defense then, and it remains vital to our continued preeminence in aviation today.

The results of this research and these experiments in aeronautics can be seen in new generations of aircraft in the air transportation system and the positive contribution that aeronautics products have made to our economy in balance of payments and the advanced military aircraft that underpin this country's defense.

Although at present we remain the world leader in aviation and aeronautics continues to be the strongest performer in our country's trade balance, this position is being seriously challenged by foreign competitors. An important contributing factor in their success has been the advanced technology included in their aeronautical products.

In other words, we no longer enjoy the large technology margin that we once did either in civil or military aircraft.

In response to these challenges, we have developed a three-fold strategy that provides the leadership to maintain a preeminent technology base in the aeronautical disciplines.

First, we recognize that we must concentrate on emerging technologies with the highest payoffs.

Second, we must assure the health and productivity of our unique laboratories and national facilities.

And finally, we must address and remove critical barriers to the introduction of new aircraft concepts.

Working with the Federal Aviation Administration, the Department of Defense, and with the cooperation of industry and the university community, NASA has formulated a comprehensive agenda that we are addressing methodically within the fiscal constraints.

Our fiscal year 1990 budget request supports this agenda with increased research funding to improve our international competitive posture and enhance the national defense. One key area to future competitive leadership is high-speed air transportation.

International air travel is an integral part of today's global marketplace, especially among the rapidly emerging economic powers of the Pacific Rim. Long-haul trans-Pacific travel is the fastest-growing market and is expected to triple by the turn of the century. This rapid growth and the extremely long flight times associated with subsonic aircraft will create a demand for high-speed aircraft to provide more effective service. While subsonic transports will still be important, high-speed aircraft will be the next plateau in competition in international aviation.

The race for the high-speed market will be intense one, since studies show that the market can support only one product. The United States cannot afford to be left behind in this critical segment of air transportation if we expect to retain world leadership in aeronautics.

Moving to the second area of increased emphasis, NASA and DOD traditionally have cooperated to provide the technology options necessary to enable the design and development of superior military aircraft. Necessary research in high-angle aerodynamics has shown that it may be possible to expand the flight envelope of the future fighter aircraft and make substantial gains in military effectiveness and safety.

Our research program will continue to provide this and other advanced technology to underwrite U.S. superiority in fighter aircraft. These two areas of increased emphasis—high-speed research, high-performance aircraft research—build upon the successes of our ongoing aeronautics research and technology program.

I would like to mention just a few notable contributions at this time. Cooperation between NASA and FAA has been stepped up to address critical issues of safety and efficiency in our air transportation system. New agreements have been reached on wind shear and other adverse weather problems, tilt rotor certification, and progress has been made on the aging fleet and human factors issues.

Together with the FAA and the industry, the aviation safety and automation research program, which was augmented in FY '89, is making strides in air traffic control and human factors. For example, a new takeoff performance monitoring system allows a pilot to monitor a single display rather than numerous gauges to decide whether to continue a takeoff or to abort.

Recent activation of the heavy-rain test facility at the Langley Research Center now allows previous small- scale test results to be validated on a large scale, improving our understanding of the ef-

fects of heavy rain. This, combined with advanced adverse-weather detection equipment, will produce safer and more efficient air transportation.

We are also investigating new avenues for solving aeronautical problems using the latest in hardware and software that computer science can provide. The numerical aerodynamics simulator (NAS) at the Ames Research Center is being used in a wide range of disciplines, including high-angle-of-attack aerodynamics, internal computational fluid dynamics, rotorcraft, power lift modeling, and support to the National Aero Space Plane Program. A second high-speed processor, the first delivered Cray Y-MP, was integrated into the NAS system and is operating in a pathfinding role. Last year more than 1150 researchers working on 350 projects accessed the simulator from 110 remote sites.

Improvements in propulsion technology historically have equated to major improvements in aircraft system performance, spurring the development of new generations of aircraft flight vehicles.

Understanding the complex flows inside an engine is the key to achieving further advances in propulsion technology, and the remarkable advances being made in computational fluid dynamics are being used to understand these flows.

In 1988 a national industry team led by the Lewis Research Center received the coveted Collier Trophy for developing advanced turboprop propulsion technology for new fuel-efficient subsonic aircraft propulsion systems. Their research into the high-speed turboprop, an advanced technology reincarnation of the propeller, has shown that it can surpass the turbofan engine for extremely efficient airliner operations. This story exemplifies how our research program develops and validates new technologies that can be incorporated in future aviation products.

The program that I have described is critically dependent on the NASA institution; that is, the facilities and the manpower that are required to conduct, manage, and support NASA's research and technology efforts. These resources are addressed in other NASA budget appropriations. Without this institutional support, the research and development program outlined here cannot be conducted. It is especially imperative that the wind tunnel revitalization program be fully supported. It is also critical that the other facility additions and the institutional funding in the construction of facilities and research and program management budgets be supported. Without a strong research and technology program, the United States leadership in aviation will be seriously at risk.

NASA's strategy for maintaining technology leadership has made substantial progress in the past, but much remains to be done. With our partners in the U.S. industry, other Government agencies, and the university community, we have prepared a roadmap and have defined priorities. We understand the tight fiscal environment, and our budget request contains only those high-payoff programs that are critical and timely.

We must pursue aggressively those environmental barrier issues that will allow U.S. industry to make informed decisions on high-speed aircraft. And we must provide the technology options to fully exploit the flight envelope of fighter aircraft.

Thank you, Mr. Chairman, and I would be happy to answer any questions that the committee may have at this time.

Mr. VALENTINE. Thank you, sir.

Let me ask you first of all if you can give us your opinion as to the chances for eventual commercialization of the tilt rotor technology.

Now, since the military has cancelled the V-22—that is where it looks like we are headed—where does that leave us with respect to utilizing what we have learned at this point to do one of the things that this program was intended to accomplish in the first place; that is, to move passengers from inner city to inner city, so to speak?

Dr. BALLHAUS. Mr. Chairman, the tilt rotor is an entirely new concept in terms of an operational vehicle, and whenever a new concept like that is introduced, there are always development risks and operational risks. One way of reducing those risks in the civil market is for the military to first undertake the development of a vehicle and operate it. Then the operators, the airlines, can assess the operational risks better, and the developers also have a better handle on the development risks.

We have been working the technology at NASA along with DOD for tilt rotors for the last four decades. We see tremendous potential both as a military concept and for civil purposes in the tilt rotor because that vehicle can fly twice as fast as a conventional helicopter and it has twice the range. It is quieter. It has tremendous potential.

Mr. VALENTINE. The military, they are at the place with this innovation that the Osprey has flown limited flight.

Dr. BALLHAUS. That is correct.

Mr. VALENTINE. I understand, I think, what you are saying about the need or the desirability of having commercial interests having something to look at and to see and to understand the benefit from progress made by the military applications.

But has what has occurred to this point, is that sufficient for us to have any reasonable expectation that private dollars will be utilized to continue the development, or are we facing the situation where if the decision made by the military experts is not reversed, that we are at the end of the line insofar as this is concerned?

Dr. BALLHAUS. Mr. Chairman, I don't think there is any question that if the military were to continue with the V-22 program, that that would facilitate the development of the civil tilt rotor in the future. I have no doubts that the tilt rotor will be developed in the future. It is just a question of timing and which country will develop it.

The United States has a four-decade investment in this technology. It would be a shame to lose that leadership because it is an area where we clearly have leadership. But I think the question remains open in the future which country or consortium of countries will first introduce the civil tilt rotor.

Mr. VALENTINE. But we will be in jeopardy of losing the initiative in this country, won't we?

Dr. BALLHAUS. Yes, I believe we are in greater jeopardy as a result of the cancellation of the V-22 program.

Mr. VALENTINE. That goes without saying.

Well, I will leave it to my colleagues if time permits. But let me get on to something else.

Yesterday the Secretary of Defense announced that the DOD will transfer the Aero Space Plane program to NASA along with $100 million of DOD's original $300 million budget request for 1990 if this action is affirmed by the space council.

First of all, I want to ask you what options does NASA have?

Dr. BALLHAUS. Mr. Chairman, we are looking internally at a number of options. None of those concepts have matured to the point where we would be prepared to discuss them at this point. In fact, we have not had any discussions at senior levels with DOD about what a future program might look like. So, I think the first thing is for us and DOD to get together and look at options and go from there.

Mr. VALENTINE. Can you give us some feel for what will be lost in terms of expected achievements in the program? In other words, what is it going to cost us in other than dollars?

Dr. BALLHAUS. If this proposal is sustained, then clearly we cannot support an X-30 flight vehicle. That would be the first casualty. Other results, I think, might clearly be a stretchout in the technology phase of the program.

But let me reiterate that we are still working options internally. And I can't really give you definitive answers at this point.

Mr. VALENTINE. Can you elaborate on that to any extent? Can you give us your judgment as to what the loss will be in terms of future benefits to this country?

Dr. BALLHAUS. Yes, Mr. Chairman. I think the national aerospace plane program is an extremely important program. One thing it has clearly done, it has revitalized the hypersonic infrastructure in this country. And about 15 years ago we essentially wiped out that infrastructure and over the last few years we have been trying to rebuild it.

By infrastructure I mean courses in universities, research in the national laboratories, and interest on the part of industry, and development and operation of hypersonic facilities. We have had to rebuild all of that. If you look at the national aeronautics goals, they deal with three regimes of flight: subsonics; supersonics; and hypersonics, hypersonics generally being flight at speeds faster than about five times the speed of sound. That is a very important regime of flight that is going to be exploited extensively in the future. And I believe that if the United States is going to maintain overall leadership in aeronautics, that we must maintain leadership in the hypersonics end of the flight regime.

Mr. VALENTINE. We have received from more than one source, I think I can say safely, rather pessimistic, gloomy forecasts as to what will happen in NASA with respect to personnel, top-quality personnel, because of the salary pay gap. Would you give us your judgment as to the overall situation in aeronautics in the NASA aeronautics programs with respect to the hiring and retaining of top-quality personnel based on today's pay schedule?

Dr. BALLHAUS. Yes, Mr. Chairman. I think it is a serious problem, especially at the executive level, and I think the problem will get worse in the future at all levels. The discrepancies between industry salaries and Government salaries is continuing to increase.

The decline of the pay raise in February, the ramifications of that have not been fully felt. I believe there is about a six-month to one-year lag time to see the full effects of that action. And I believe that we are at a high risk in NASA of losing a number of senior executives within the next year.

We have seen some go out the door already, at fairly high levels. I think that is only the beginning, frankly. Something must be done about this problem. The salary gap is getting too large.

In terms of other areas, I think also that the civil service system needs to be adapted to the needs of modern R&D laboratories and the needs of NASA. The existing civil service system, I believe, is too rigid. I have been personally trying to work that problem over the last several years, but NASA has also been trying to work it. The former NASA administrator, Mr. Fletcher, was a strong supporter of an alternate personnel system, one that would give us more flexibility in being able to recruit and retain talented people.

One very important point that needs to be made is that you can always fill a chair with somebody, but when we are allocating the taxpayers' money to managers to manage prudently, it is very important that you get people that have the best judgement, and that means the right technical, managerial, and administrative individuals. It is getting more and more difficult for us to recruit those kinds of people. It is also getting more difficult to retain those kinds of people. So, I see it as a very, very serious problem.

Mr. VALENTINE. Some of my colleagues here might disagree with this. But I think it unrealistic to think that Congress will revisit the question of the pay increase generally at this session of Congress. It was quite a traumatic experience for a lot of us. And I don't think that we are going to give it a serious consideration further to adjusting our own pay, and I don't—I suppose, human nature being what it is, that there would be much enthusiasm for taking on this issue with respect to others such as Federal judges and others in top positions in the executive branch.

Would you supply to this committee or to me on a personal basis some of your thoughts in writing as to how we might construct some plan to address the problem that you are talking about other than just the general pay increase, some method similar to, well, for lack of a better example, the incentive system that exists in the Armed Forces to bring in professional people, doctors and lawyers and so on?

Dr. BALLHAUS. I would be happy to do that, Mr. Chairman.

Mr. VALENTINE. Mr. Lewis?

Mr. LEWIS. Thank you, Mr. Chairman.

The aerospace industry produces the largest positive trade surplus of any business in the United States, and how does NASA aeronautics research contribute to the industry's strong position in world trade?

Dr. BALLHAUS. In order to remain competitive, it is important that we have the best products, and that means having the best technology in our products. The investment that we make in NASA I think contributes in two major ways: One is the new technology that gets incorporated in industry products; and the second is through the development and operation of the major facilities that we operate in NASA which not only contribute to the research but

also are critical to the development of new aircraft systems that the industry produces.

Mr. LEWIS. I know you can't do it now, but I would like to know how you feel industry would be impacted if NASA's aeronautical research budget was cut significantly, including the National Aero Space Plane?

Dr. BALLHAUS. There would be an immediate impact on the development of new aircraft systems. That would come through the scale-back of some of our facility operations. The wind tunnels at NASA, for example, some of the premier wind tunnels are backlogged over two years, with industry development activities supporting DOD and also the civil sector. There would be an immediate impact on those development activities.

Now, that is a serious problem. But there is also another serious ramification, and that is the new technology development would either cease or have to be picked up by other agencies. For example, much of what NASA does supports civil industry but also DOD and the FAA. Other agencies would have to pick up that part of the basic research which they do not now fund.

In terms of impact on industry, I think that there is a lag time between when you would make that cut and when you would feel the effect, because the technology that is incorporated in current products is technology that was developed a number of years ago. So, the technology that will be incorporated in aircraft that are produced at the turn of the century is the technology that we are developing right now.

Mr. LEWIS. I have a great concern about technology transfer. NASA has worked closely with industry and universities in providing technology, which has been instrumental in maintaining aeronautical preeminence. I would like to know how that NASA ensures that the research programs meet the needs of both industry and universities.

Dr. BALLHAUS. Mr. Lewis, we have an advisory committee structure. We have an aeronautics advisory committee made up of members that represent a cross-section of the industry and the university community and also other Federal agencies. And that advisory committee reviews our program several times a year, comments on the content of the program, and suggests modifications.

In addition to that, we also have the ASEB, which is a part of the National Research Council, which advises us on policy-oriented or technical issues.

Mr. LEWIS. Some of the NASA scientists indicate that we cannot keep research results and technology from other nations for any longer than two years. Should NASA's programs for keeping aviation technology in the United States be strengthened?

Dr. BALLHAUS. Yes, Mr. Lewis, I believe it should. I believe that we need greater authority to restrict the dissemination of technology that can have economic benefit to foreign countries. That is difficult right now with the Freedom of Information Act.

Mr. LEWIS. I was going to ask you, should the Freedom of Information Act request be restricted to accomplish this?

Dr. BALLHAUS. I am not an expert on legislation, but I would say that NASA—

Mr. LEWIS. I want your gut reaction to the question.

Dr. BALLHAUS. I personally think that NASA should have the authority to control the dissemination of technology to foreign countries. Right now we have difficulty in restricting that dissemination.

Mr. LEWIS. We have on this subcommittee recommended major efforts in revitalizing our wind tunnels, and you have responded with a five-year revitalization program. And you discuss this in your testimony.

What is the status of upgrading the wind tunnel at Ames, the 12-foot wind tunnel?

Dr. BALLHAUS. The 12-foot wind tunnel refurbishment is continuing. We are dismantling that facility right now. We had numerous cracks in the pressure shell. One is ten feet long and about 80 percent of the way through the structure, and when we discovered that a couple of years ago, I immediately derated that facility to one atmosphere. We expect the designs, all of the designs with one exception, to be completed and in our hands by the end of April.

One design that is outstanding is the control system, and we should have that in our hands by the end of May. So, that is progressing well.

We would hope to have the work packages available for bid sometime around October of this year, which is a little optimistic, but that is a target for us to shoot for, and then to have the integrated systems test, which is done after the completion of the construction, completed sometime in 1992.

Mr. LEWIS. Where do you feel that you have had any slippage in the 12-foot wind tunnel revitalization program? Will U.S. industries have to go to European facilities in order to meet their development requirements?

Dr. BALLHAUS. They will have to find some way of getting around that problem. The 12-foot wind tunnel is a very important facility, as you know. Virtually every aircraft that has been developed in this country in the last 30 years has gone through that facility. It is a critical facility.

There are similar facilities in Europe, and each company would have to make up its own mind to what extent it was willing to risk that. But there are risks on both sides. If you don't test, then you run the risk of not getting the right performance data, which requires high Reynolds number facilities, and you may give away your technology if you test in foreign facilities. And they have to make that decision on a case-by-case basis.

Mr. LEWIS. Air safety is one of my areas of interest, and we have human error or human factors program—both NASA and the FAA. And I would like to know what your plans are for studying the causes of human error and ways of reducing errors with the program that you are establishing at Ames?

Dr. BALLHAUS. We were fortunate to get an augmentation last year of about $7.5 million in the aircraft safety and automation area, and we are using that to strengthen our human factors research in several areas. One is, as automation increases in the cockpit, we are starting to see new types of errors. Pilots don't make the same kinds of errors they used to. We are seeing new errors resulting from the automation.

So, we have to learn how these errors occur and learn how to control them. Pilot boredom, for example, is something that results from automation. You have to learn how to control that.

We do have a large database of aircraft incidents, near misses and so forth, that we catalogue and we do trend analyses on that database. We have over 70,000 incidents catalogued in that database. We look for error trends, and then we work with the airlines, with the pilots, with the industry, to try to replicate those errors in our simulators to understand them and then develop procedural techniques or technology that will eliminate those errors in the future.

Mr. LEWIS. Thank you, Mr. Chairman. I will hold any further questions that I have.

Dr. Ballhaus, it is always a pleasure to have a dialogue with you. Thank you very much.

Dr. BALLHAUS. Mr. Lewis, thank you very much.

Mr. VALENTINE. Mr. Campbell?

Mr. CAMPBELL. Thank you, Mr. Chairman.

Could I pursue that last topic. It is an area that I don't know as much about as I wish I did.

The use of the Cray computer as an alternative or as a part of a simulation in a wind tunnel, could you please speak, Dr. Ballhaus, to this question: To what extent are you using the Crays now as part of an integrated testing facility with the wind tunnel and to what extent can they substitute for wind tunnel testing?

Dr. BALLHAUS. There are several issues there. One is the aerodynamic design of a vehicle. And clearly the role of the wind tunnel is changing. It is becoming more one of validation, whereas the computer is becoming much more of the workhorse in the day-to-day design.

The reason is very simple: Building wind tunnel models is expensive and it takes a long time to get the turnaround on the model, whereas you can sort through thousands of configurations on a computer in a very short amount of time looking for the optimum shape. The performance depends very strongly on the shape. So, we see that change occurring.

Now, in terms of the human factor side of it and surveying the database of incidents, we don't use the supercomputers or the Cray for that because it is not a computationally intensive problem, but we do use fairly simple algorithms to sort through these incidents and try to look for trends. So, really, classification techniques to look for error trends.

Mr. CAMPBELL. So, if it had not been for the implementation of the supercomputers, the utilization of the wind tunnel would have been substantially more and you would have gotten beyond your capacity a lot sooner?

Dr. BALLHAUS. I believe you are always going to use as much wind tunnel time as is available to you. It is a resource that is always going to be saturated. The question, though, is what kind of a design do you have when you go into the wind tunnel. With the supercomputers we go into the wind tunnel with a very refined design. So, the wind tunnel then is primarily to check and make sure that the design is correct and that we haven't missed anything.

I don't think, for example, that we are going to see wind tunnels shut down in the very near future because we have more computers, and I think that we will use the wind tunnels to the extent we can and then we will use the computers to the extent we can.

Mr. CAMPBELL. The point that I was leading to was that. If there was an environment of dwindling resources, do you foresee a greater reliance, cost-effective reliance, upon computers if we continue this trend and less on the wind tunnel? I think you have explained to me how the two continue to be used together.

And I have one other line of inquiry. That is, the NASP program. I think you were very diplomatic in your description, but I will tell you my interpretation is it is dead, given what DOD is doing.

Now, if that is too indelicate a position for you to agree with, you can say that. But I would like your reaction to that characterization.

Dr. BALLHAUS. Mr. Campbell, I hope that your assessment is incorrect. I think it is an extremely important program and that we have to find a way to maintain the hypersonic infrastructure that we have built up and move forward. And I believe that there are ways that we can do that.

Mr. CAMPBELL. Within the DOD numbers?

Dr. BALLHAUS. I would hope at some point that we would see that situation remedied. However, I think it is extremely important that if NASA does take on the program under the constraints that were mentioned, that we find a way to maintain the intent of the program.

I mentioned before that we would not be able to support a flight vehicle but we ought to be able to maintain the technology development and focus on the highest-priority items to keep the concept alive because I think it is an extremely important one.

The aerospace plane is a concept that has a tremendous spectrum of opportunities for vehicles in the future. If it works, it will be the ultimate launch vehicle in terms of being able to take off horizontally, to achieve orbit in a flexible way, many possible civil and military applications that could be served by this technology program.

And I want to emphasize that it is a technology program. We are not trying to develop an operational vehicle here to start out with. So, I would hope that we can keep that concept of an aerospace plane alive and continue to work the technology. I think that is extremely important.

Mr. CAMPBELL. My last question deals with the commercial side of that. Do you foresee any possibility of involving our American commercial avionics and aeronautics firms in joint venture or consortium which could assist in a dwindling resource environment, the resources necessary to develop a NASP?

Dr. BALLHAUS. It is possible. As you know, we did form a materials consortium to try to share the research and minimize the cost to get the same amount of work done. It is possible that we could have a consortia of companies, engine companies, airframe companies, to proceed with aerospace plane activities.

But I do not see that as being privately funded. I think the risk is just too great. The aerospace plane is a high-risk and potentially

very-high-payoff program, a risk that I think is beyond the capability of most companies—of all companies in the United States—to undertake.

Mr. CAMPBELL. You may well be right. But my question is, have you explored in any practical sense such an alternative from a consortium, a group of American firms?

Dr. BALLHAUS. To reduce the cost of doing the program?

Mr. CAMPBELL. Exactly.

Dr. BALLHAUS. That is being looked at.

Mr. CAMPBELL. I will be interested in what results you have because I think realistically we probably will be working with less and less Federal money. And assuming we get past the antitrust problems, to get some American firms working together, that may be an alternative that would merit attention.

Thank you, Mr. Chairman.

Mr. VALENTINE. Thank you, Mr. Campbell.

Mr. Rohrabacher?

Mr. ROHRABACHER. Would you disagree with the assessment that by defunding a portion of the Department of Defense for the aerospace plane that we are raising the white flag for America's future?

Dr. BALLHAUS. You put me in a difficult position, since I represent the Administration at this hearing.

Mr. ROHRABACHER. I guess I could take that as an answer. That is fine.

Do you know much about—can you detail for us what priority some of America's potential competitors and adversaries are putting on the development of hypersonic transportation?

Dr. BALLHAUS. Mr. Rohrabacher, at this point in time we clearly have the lead in hypersonics because of the investment that we have made in aerospace planing. However, there is a GAO report—I am not sure that it has been issued yet—but people at NASA headquarters have been briefed on it. I missed that because I was out at Ames when they briefed us. But they have a fairly extensive assessment of the technology that is being developed in foreign countries.

I can give you a summary of what I believe that assessment says. There is a strong effort in Europe in pursuing the Sanger concept, which is a two-stage orbit vehicle, the first stage of which is air-breathing propulsion, and also would have the potential to be a hypersonic transport around the MACH 6 regime. We believe the Soviet Union is working on a MACH 5 transport. The Japanese have hypersonic facilities and are working on engine concepts and space plane systems studies.

Other areas of hypersonics, the French have their Hermes project, which is not an air-breather, it is more like our shuttle but without cargo capability. It is primarily a people carrier. It would be launched on top of an Ariane 5. The Japanese have a concept called Hope, which is a shuttle-type concept that they would launch on their H- 2 rocket.

Those are some of the examples.

Mr. ROHRABACHER. At no time in the last two decades have we faced stiffer competition in an area, a specific area of research. And yet, this is exactly the time we are cutting back on our own

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research program in that specific area. Is that what we are facing now?

Dr. BALLHAUS. The competition the United States is facing in aeronautics is unprecedented in the last 20 years, that is certain.

Mr. ROHRABACHER. And we could blink our eyes and just wake up—time goes real fast when you're in jobs that you like—and you blink your eyes and all of a sudden we could face a situation where the Japanese have totally leapfrogged us in the next stage of technology. Isn't that right? And we can just be unable to catch up if we sort of let that happen.

Dr. BALLHAUS. I would characterize it a little differently. I think the investment to catch up would be much greater, and you reach a point that if you get far enough behind that you can't catch up with any investment.

Mr. ROHRABACHER. And in terms of this Defense Department cut, isn't there really a defense job that this National Aerospace Plane actually fulfills and shouldn't the Defense Department actually pick that portion of the research up?

Dr. BALLHAUS. Mr. Rohrabacher, I cannot speak for the Defense Department. They have to assess their situation and make their own conclusions.

Mr. ROHRABACHER. Let me ask you this: If we had the National Aerospace Plane as envisioned or as potential, could we take off from a base in the United States which would then make it unnecessary for us to have to have a base perhaps far overseas and conduct a mission, let's say, over Libya and be back in time for lunch?

Dr. BALLHAUS. There are many options that you have when you travel at those speeds. I am not an expert on defense matters. I really cannot comment on potential defense applications.

Mr. ROHRABACHER. So, anyway, not hearing a denial, it seems to me that we definitely have a mission for this. The end of our research here would be a defense mission, yet the Defense Department doesn't want to participate. And I don't expect you to answer that.

Thank you very much.

Mr. VALENTINE. Dr. Ballhaus, let me ask you this. I don't know whether you can answer it or not. But do you think—whether you would want to—do you think that if the Aero Space Plane were stamped something else, that we changed the name of it and called it the "strategic defense initiative contact vehicle," A-1 mounted, wouldn't we be in a better position to keep it in the budget—I withdraw that question.

[Laughter.]

Dr. BALLHAUS. Thank you.

Mr. VALENTINE. Let me ask you. I have a couple of questions that I would like to get in here.

While the Aero Space Plane, the development of it, is situated in the Department of Defense and when it becomes in the future, as it looks like this is where we are headed, a part of NASA, will it be exposed to different influences that result from priorities, internal rivalries? When it was stuck over there with the Defense Department, presumably there were no rocket propulsion systems to contend with it. Does it now run into a situation where it has, in addition to fighting the Administration and Congress for money, to

have another fight with the powers-that-be in NASA as to whether we need to deemphasize what we are doing now and go to this new thing?

Dr. BALLHAUS. Mr. Chairman, NASA is in a very difficult position in terms of requiring substantial increases in its budget to just pursue the program that we have on the books right now with trying to increase the shuttle flight rate and get it up to an equilibrium level and also to develop the space station. So, NASA is severely challenged in trying to maintain the budget that it needs to do the program that we have already as a country committed to.

It would be hard for me to imagine that NASA could take on the program as it currently exists at the funding level that currently is required, including the funding to support a flight vehicle with the budgets that we are likely to get in the next few years.

However—and let me take it a step further and say that I think it is unlikely that we would develop an X- 30 without DOD participation. It is not impossible, but very unlikely.

But let me say that I think that the acting administrator, Mr. Myers, who will be acting for the next couple of weeks, strongly supports the program and his successor, Admiral Truly, I believe is a strong supporter of the program.

So, in terms of senior management support in the agency, I think there is strong support for an aerospace plane activity.

Mr. VALENTINE. Isn't the Aero Space Plane almost of necessity the wave of the future? We really on down the line insert our Nation into space by rocket power or by an airplane that can fly from an airport. Doesn't it follow as night the day that we will not be able to continue to do this thing with rockets, that we have got to find a better way and the only other better way is by airplane?

Dr. BALLHAUS. It does offer the potential to reduce the cost of getting to orbit. That is absolutely true. And the concept and the technology for doing that has not been matured, as you know, and that is the purpose of the aerospace plane program. So, it is to give us that option in the future.

Mr. VALENTINE. I suppose it is beyond our grasp, and perhaps unrealistically idealistic, but we do suffer from a reliance on military-motivated,-generated advancements in technology because it seems to me that it is more closely tied to the passions of the moment.

Do you think that we can or we should try to change the situation whereby we don't have to rely on the situations that we are here—it is philosophical, but you know what I am talking about, the major aviation advances in this country, the B-47, the B-52 which led to the 707 and today's intense international competition. Here we were relying on the military technology advancements in tilt rotor, and then the V-22 is cancelled, bam. Shouldn't we try to change all that?

Dr. BALLHAUS. I think that is a very important question we face as we try to maintain leadership in the next two decades. The current aeronautical policy does allow the flexibility to adapt to that situation. It depends on the degree to which we are willing to support systems activities within NASA and also validation of new concepts. The aeronautical policy does allow for that.

However, at least in the last decade, we have not invested very much money in the systems level activities and in technology validation, large-scale validation of systems. But the policy allows for the country to respond to that challenge when the need arises.

So, that policy is in place, and the question is how we should implement it and how we generate the budgets to support those activities.

Mr. VALENTINE. Do you gentlemen have any further questions?

Mr. LEWIS. Mr. Chairman, I would just like to make the statement that this subcommittee has the oversight responsibilities for the NASP, and I can assure you that though the gentleman California feels this is the end of the NASP plan, I don't think so.

And I think unfortunately or fortunately maybe this is a good time in which I believe we in Congress, the Administration, the country as a whole is in a year of decision as to where we really do go with our research programs, our development programs, as well as what we are going to do in space and that sort of thing.

And I believe it is probably a good thing that it has come and the cutbacks in the defense budget will spur all of us to look at these things more clearly and not through a kaleidoscope but through the periscope that determines just where our goals are going to be established.

And I firmly believe that there will be a NASP plane, and I believe that whether the Department of Defense wants it or not they are going to be part of the program. They are also going to be part of the Hurricane program whether they want to be part of that or not. So, that is a personal thing.

Nonetheless, I think it is good that it happened, and I think that NASA is going to have a major role as always in the research and development programs, and I guess we are just going to have to maybe reestablish some priorities, but we are also going to have to recognize that it is this year we do it or this year that we tell our adversaries in research and development in other countries both from an economic viewpoint and from research that we are going to step back and let you guys carry the ball and we are going to be also-rans. I just don't think that is going to happen here.

Thank you, Mr. Chairman.

Mr. VALENTINE. Mr. Rohrabacher?

Mr. ROHRABACHER. I hope my colleague is right, and I am overly pessimistic.

Mr. LEWIS. Good. I am overly optimistic.

Mr. VALENTINE. Well, thank you very much. You have been very helpful to us. If you would give attention to that detail, we might surprise you with some activity in that area. I am talking about the dinero.

Thank you very much.

[The prepared statement of Dr. Ballhaus follows:]

NASA
National Aeronautics and Space Administration

Hold for Release Until
Presented by Witness
April 26, 1989

Subcommittee on Transportation, Aviation and Materials

Committee on Science, Space and Technology

House of Representatives

Statement by:

Dr. William F. Ballhaus, Jr.
Director, Ames Research Center
National Aeronautics and
Space Administration

101st Congress

STATEMENT

of

Dr. William F. Ballhaus, Jr.
Director, Ames Research Center

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

Subcommittee on Transportation, Aviation and Materials
Committee on Science, Space and Technology
United States House of Representatives

Mr. Chairman and Members of the Subcommittee:

I am pleased to present NASA's FY 1990 Aeronautics Research and Technology budget request. This budget supports a program constructed to strengthen the United States' leadership in aeronautics. It provides for a foundation of advanced technology upon which our industry can build to maintain our competitive posture in global aviation markets.

The United States has long been the world leader in aviation. The aerospace industry is the leading exporter among all high-technology industries. Our aeronautical products continue to provide the largest positive contribution to our country's trade balance and our military aircraft are superior in performance and reliability. But our leadership is being challenged today as never before.

Our dominance in important worldwide aviation markets is being challenged by escalating foreign competition. These competitors recognize the importance of advanced technology as a competitive factor and are committed to continuing the aggressive investments required to maintain their momentum in research and development.

NASA recognizes the serious effect that a loss of leadership in aeronautics could have on the economy and military strength of the United States. NASA, with its industry and university partners, has worked to provide technology which is instrumental in maintaining aeronautical preeminence. Through this close relationship with industry and the users of its products, we understand the technological advances required to keep the United States in front, and we have taken steps to reorient our program to keep abreast of changing times. However,

there is much more that needs to be done to assure continued United States leadership in aeronautics.

Technology always has been an important factor in aviation, but it is becoming even more critical as we push beyond the traditional frontiers of aviation. The NASA aeronautics research and technology program has been planned to respond forcefully to this growing international competition and to the goals contained in the "National Aeronautical R&D Goals" and the subsequent "Agenda for Achievement," published by the Office of Science and Technology Policy.

These goals--in the hypersonic, supersonic cruise, and subsonic speed regimes--hold many technology challenges.

- Transatmospheric vehicles that cruise at hypersonic speeds and can transition into Earth orbit will require new engines to propel them and entirely new materials and structures to withstand the intense heat.

- High-speed civil transports to meet the burgeoning needs of long distance air travel will challenge our ability to integrate propulsion, aerodynamics, structures, and controls technologies into safe, efficient, environmentally acceptable, and affordable aircraft.

- Subsonic transports will have to be much more efficient, with revolutionary turboprops replacing the familiar turbine engines for many applications; with new levels of automation and control to enhance safety in the increasingly crowded skies; and with new types of shorthaul aircraft, such as a vertical lift tiltrotor capable of operating from city centers, needed to relieve already overburdened airports.

- Military aircraft will have to operate from damaged runways and be capable of sustained supersonic speeds, yet be agile and maneuverable as no aircraft has ever been before.

NASA has a leadership role to play in developing the technology base in aeronautical disciplines necessary to meet these challenges. Our aeronautics program strategy is:

- to emphasize emerging technologies offering the potential for major advances in aeronautics capabilities;

- to assure the health and productivity of our unique laboratories and national facilities; and,

- to address critical barriers to the introduction of new aircraft concepts.

In line with our first strategy element, to emphasize high-payoff technologies, our FY 1989 program reflects increased emphasis on advanced propulsion concepts, advanced composite materials, and aviation safety and automation. Consistent with this, our FY 1990 program will focus on research aimed at providing the technology for unprecedented levels of maneuverability and agility for next generation military aircraft. This flight research will investigate the potential benefits of multi-axis thrust vectoring for high angle-of-attack maneuvering and flight.

Our second strategy element, assuring the health and productivity of our key facilities, is addressed through the five-year NASA Major Wind Tunnel Revitalization program, which began in FY 1989.

In the third strategy element, critical barriers to new aircraft concepts are addressed and high-payoff technologies are targeted for development. A Civil Aeronautics Technology Development and Validation Plan was prepared in 1988 at the request of the Senate Committee on Commerce, Science, and Transportation. This plan defines advanced technologies required for leadership in civil aviation. We also have defined those technologies required to maintain superiority in military aircraft.

With the help of the Federal Aviation Administration (FAA) and the Department of Defense (DOD), and in cooperation with industry and the university community, NASA has formulated a comprehensive agenda that we are addressing methodically within fiscal constraints. The FY 1990 budget request, summarized in Figure 1, supports this agenda. It includes increased research funding for major enhancements in aircraft performance, improved international competitive posture, and enhanced national defense.

One area that will be key to future competitive leadership is high-speed air transportation. International air travel is an integral part of today's global marketplace. Nowhere is this more true than among the rapidly emerging economic powers of the Pacific rim. Long-haul transpacific travel is currently the fastest growing market and is expected to nearly triple by the turn of the century. Because of this projected rapid growth and the extremely long flight times with subsonic aircraft, there will be an increasing need for future high-speed aircraft to provide more effective service. While subsonic transports will continue to be an important market segment, these high-speed aircraft will be the next plateau of competition in the international aviation arena. The competition for the high-speed market, which studies show the market can support only one product, will be intense. The U.S. should be a key player in this critical segment of air transportation if we expect to retain a favorable trade balance and world leadership in aeronautics.

NASA-sponsored studies indicate that, with sufficient technology development, these future high-speed aircraft could be economically competitive with long-haul subsonic aircraft. Currently, however, critical environmental concerns about atmospheric impact, airport noise, and sonic boom present powerful private sector disincentives. The NASA High-Speed Research program will address the

resolution of these barrier environmental issues and develop the basis for evaluating technology advances that can provide the necessary environmental compatibility. Resolution of these critical environmental issues will place the U.S. in a position to make informed decisions on high-speed aircraft technology development in the future.

The program builds on NASA's extensive efforts in upper atmospheric research and previous experience in airport noise reduction technology and sonic boom reduction. The atmospheric research involves two elements: long-term atmospheric chemistry assessment and low emission combustion research. The long-term atmospheric chemistry assessment will use sophisticated atmospheric particle transport models and complex atmospheric chemistry models to analyze the potential long-term effects of aircraft emissions on the stratosphere. In parallel with this effort, the low emission combustion research will develop and test alternative methods for reducing or eliminating engine exhaust products that cause ozone depletion. The primary focus is to develop advanced technology combustor designs which produce very low amounts of nitrogen oxide emissions.

The airport noise reduction research addressed in this program involves research on alternative engine cycles and jet noise suppression aimed at providing the same acoustic levels achieved by today's quietest subsonic aircraft. This research will expand on the results of previous acoustic fatigue testing (Figure 2) to include anechoic chamber tests of advanced technology jet noise suppressor designs. Airport noise calculations will examine projected levels for alternative aircraft and engine systems.

The third major segment of the program, sonic boom reduction, includes both aircraft configuration research aimed at reducing sonic boom levels combined with human response evaluations to define criteria for acceptability. Aircraft configuration research will focus on design analyses and wind tunnel testing of low sonic boom configurations as well as analysis and experimental research on supersonic laminar flow control. Selected flight research efforts will be conducted to verify the analyses and wind tunnel test results. The F-16XL aircraft, shown in Figure 3, was recently obtained from the Air Force and will be used as a flying testbed to investigate the feasibility of applying laminar flow control techniques, developed for subsonic transports, to supersonic flight with delta wing aircraft.

NASA and the DOD traditionally have cooperated to provide technology options to allow superior military aircraft. The NASA research in high angle-of-attack aerodynamics has shown that it may be possible to greatly expand the flight envelope of future fighter aircraft with substantial increases in military effectiveness. The military wants to exploit these lower-speed, high angle-of-attack portions of the flight envelope to achieve tactical advantages through increased agility and maneuverability. We will investigate this regime from a flight science perspective, achieving an understanding of the physics and validating our design tools. To date, experiments in NASA wind tunnels have demonstrated the capability to achieve post-stall maneuvering at angles-of-attack approaching 90 degrees. Our computational codes (Figure 4) are being developed to predict these highly non-linear flow conditions. The F-18 High Angle-of-Attack

Research Vehicle (HARV) (Figure 5) is generating flight data to validate our results through angles-of-attack up to 30 degrees. Our requested augmentation will expand the flight validation to extremely high angles-of-attack approaching 90 degrees. This will be accomplished through modification of the HARV with a thrust vectoring control system to allow sustained operations at extremely high angles-of-attack. This will permit thrust vectoring beyond stall as well as evaluation of advanced maneuver management concepts. The resulting predictive codes and design methodologies will enable DOD to have the option of incorporating this high-payoff technology into the design of future military aircraft. The potential advantages of a future military fighter with an ability to fully exploit the flight envelope include increased mission effectiveness as well as enhanced safety.

At this point I would like to describe a few of our recent major accomplishments that reflect our strong program in high-payoff emerging technologies.

We have enhanced the productivity of the Nation's leading computational capability by greatly increasing the computing power of the Numerical Aerodynamic Simulator (NAS) at the Ames Research Center. A second high-speed processor, the first delivered Cray Y-MP, was integrated into the NAS and is presently operating in a pathfinding role. The NAS has been used in a wide range of aeronautical disciplines including high angle-of-attack aerodynamics, internal computational fluid mechanics, rotorcraft and powered lift modeling, and National Aero-Space Plane support. During the last year more than 1,150 researchers, working on 350 projects, accessed the NAS from 110 remote sites.

As part of our work in computer science, alternative architectures such as massively parallel processors (Figure 6) are being investigated for possible application to aeronautical problems. This work will expand as we develop the computing power for new and innovative approaches to solving complex multidisciplinary problems and to integrating individual computational tools into total system solutions. We are actively working with the other members of the government High-Performance Computing team to define NASA's role in this critical multi-agency national program.

The safety and efficiency of the Nation's air transportation system has come under increasing scrutiny in the recent past. This national need has sparked a renewal of cooperation between NASA and the FAA in those areas where our mutual interests and expertise overlap. New agreements on wind shear/adverse weather and tiltrotor certification have been negotiated, and we are actively cooperating with the FAA in the areas of aging aircraft and human factors. The Aviation Safety and Automation Research Program augmented in FY 1989 is off to a good start and has been coordinated with FAA and industry efforts in air traffic control and human factors. One recently developed concept, the Takeoff Performance Monitoring System, has the potential for increasing pilot awareness and enhancing flight safety (Figure 7). This system allows a pilot to monitor a single display, rather than multiple gauges, to determine whether to continue a takeoff or abort. Flight validation by NASA research pilots and evaluation by line pilots from major airlines have proven the concept to be viable, and the research

results are being transferred to industry. Flight in adverse weather is known to present dangers, but the actual effect of heavy rain on the aerodynamic performance of an airplane's wing has not been well understood. Recent activation of a heavy rain test facility at the Langley Research Center (Figure 8) means that previous small-scale test results can be validated in large scale. This improved understanding of the effects of heavy rain, when combined with the results of flight evaluations of advanced adverse weather detection equipment, will result in safer and more efficient air transportation.

Basic research in subsonic aerodynamics continues to produce promising results. Wind tunnel tests have shown that wings with a crescent planform (Figure 9) have a 3-4 percent reduction in induced drag when compared to an elliptical wing which was previously thought to be the theoretical optimum. This improvement in drag is accompanied by enhanced aerodynamic performance near stall. This research could lead to a low-speed wing planform designed for safer and more efficient general aviation airplanes.

Rotorcraft and powered lift research continues to advance as an important segment of the NASA aeronautics program. The recently upgraded National Full-Scale Aerodynamics Complex (NFAC), which became operational last year, is a key facility for rotorcraft and powered lift research and for supporting major DOD systems development. Rotor performance predictions were recently validated in the 40-foot by 80-foot wind tunnel section of the NFAC in support of DOD's V-22 tiltrotor development (Figure 10). We also are analyzing the complex flow fields about powered lift vehicles in ground effect using advanced computational fluid dynamics techniques (Figure 11). Initial comparisons of experimental and computational results have been very promising, and the capability of these computational techniques is being expanded to include improved turbulence modeling and rate-of-descent effects. Integrated flight and propulsive controls, as well as ejector performance, are being evaluated in full scale and at operating temperatures using the E–7 model (Figure 12). The results of these tests will be used to validate small-scale, cold-air tests and further refine our design and analysis techniques.

Composite materials are being used more often in current and future airframe designs because they are lighter and stiffer than conventional metallic aircraft structures. A new thermoplastic material, LARC TPI, developed by the Langley Research Center, is currently being evaluated by the aircraft industry. Combined with innovative manufacturing techniques, such as thermoforming, this material offers the potential for improved aircraft performance with reduced production costs. Our research in advanced composite materials, which was augmented last year, has been well coordinated with industry and universities. The focus is on advanced materials, such as toughened thermosets and high-temperature thermoplastics, and the innovative design methods to optimize the use of these materials in aircraft structures. Our goal is to develop composites technology for primary airframe structures which will result in a 40 percent reduction in airframe weight and a 25 percent reduction in acquisition cost. This will provide airframes which can be constructed inexpensively and operated efficiently.

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High-temperature materials for application to future engines and hypersonic airframes require strength and durability that are not obtainable today. Material systems, such as advanced intermetallics, that have good high-temperature capabilities often lack the strength for engine or airframe applications. Recent experiments have shown that alloy modifications using minute quantities of additives can significantly increase the room temperature ductility of intermetallics, enabling their use in airframe as well as engine applications. This has the potential to double the life of high-temperature components while providing a 30 percent reduction in weight.

Investments in propulsion technology have historically provided a major share of improvements in aircraft system performance, enabling the development of new generations of aircraft and flight vehicles. Understanding the complex flows inside an engine is the key to achieving further advances in propulsion technology. The remarkable advances that have been made in computational fluid dynamics are being applied to develop an understanding of flows in engines. Previously developed codes model the flow through a single stage of turbomachinery with various levels of complexity. A new approach is now under development that will analyze the highly complex vortical flow structures that occur in multiple stages of turbomachinery using existing supercomputers. The initial version of an expert system was demonstrated that provides a user-friendly interface to make these codes more easily available to a wider range of researchers and potential users.

Another recent accomplishment is an outstanding example of how we successfully apply our strategy. In 1988 a NASA/Industry team was awarded the Collier Trophy, one of the most coveted awards in Aeronautics. The award was given for "developing advanced turboprop propulsion technology for new fuel efficient subsonic aircraft propulsion systems" (Figure 13). The high-speed turboprop, an advanced technology reincarnation of the propeller, has proven to be substantially more efficient than the jet engine for airliner operations. This spectacular accomplishment, led by the Lewis Research Center, began in the late 1970's with a few good ideas to save fuel. Analyses and systems studies were followed by small-scale model and component testing in NASA and industry facilities. Predictive computer codes were refined and validated. This experimental and analytical base provided the Advanced Turboprop Propulsion team the confidence to design, build, and flight test large-scale hardware. This story exemplifies the way our research program develops and validates new technologies that can be incorporated in future aviation products.

The program that has been described is critically dependent on the NASA institution, that is, the facilities and manpower that are required to conduct, manage, and support NASA's research and technology efforts. These resources are addressed in other NASA budget appropriations. Without this institutional support, the research and development program outlined here cannot be conducted. It is imperative that the Wind Tunnel Revitalization Program be fully supported. It is also critical that the other facility additions and the institutional funding in the Construction of Facilities and Research and Program

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Management budgets be supported. The Office of Management and Budget has recognized this need and has authorized NASA a new personnel ceiling of 24,007. Within that allocation we expect some 250 additional full-time civil service personnel to be assigned to the three Research Centers in Fiscal Years 1989 and 1990. These positions also must be supported in the NASA Resources and Program Management budget to permit the hiring of these critically needed people.

Leadership in aeronautics is crucial to our international balance of trade and national security and to the safety and efficiency of our air transportation infrastructure. We have a NASA strategy for maintaining technology leadership and, while we have made substantial progress in the past, much remains to be done. In partnership with U.S. industry, other government agencies, and the university community, we have prepared a roadmap and have defined priorities. We are aware of the tight budget environment and have requested only those high-payoff programs that are critical and timely. In FY 1990, we must maintain the integrity of our Wind Tunnel Revitalization plan, aggressively pursue those barrier technology issues that will allow U.S. industry to make informed decisions on high-speed aircraft, and provide the technology options to fully exploit the flight envelope of fighter aircraft.

The ongoing NASA aeronautics research and technology program is vigorous and productive. We conduct pioneering research in emerging technologies, selectively conduct the highest payoff systems technology programs, and produce technologies that industry can incorporate into future products. The results of our research are major factors in our country's aeronautical leadership. We have provided much of the technology base that has enabled the United States to be the world leader in aviation, but our task is not done. Today our leadership is being challenged on many fronts. The question is not whether we can afford to take on these challenges. The question is whether we can afford not to.

Thank you, Mr. Chairman. That completes my prepared statement. I would be pleased to address any questions you may have.

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R&D BUDGET
($,M)

	FY 1990
AERONAUTICS R&T	**462.8**
R&T BASE	335.7
HIGH PERFORMANCE AIRCRAFT RESEARCH	(8.0)
HIGH PERFORMANCE COMPUTING	(2.0)
SYSTEMS TECHNOLOGY	127.1
HIGH-SPEED RESEARCH	(25.0)

Figure (1)

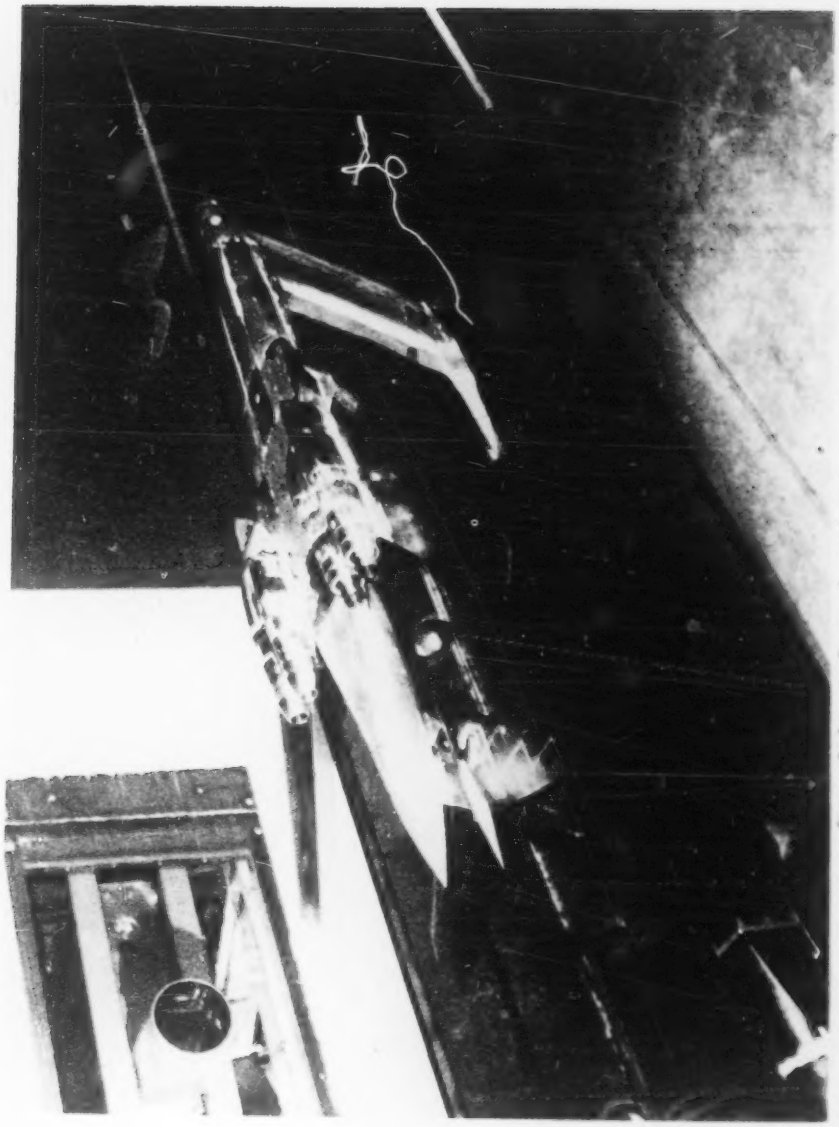


Figure (3) F-16XL Research Aircraft

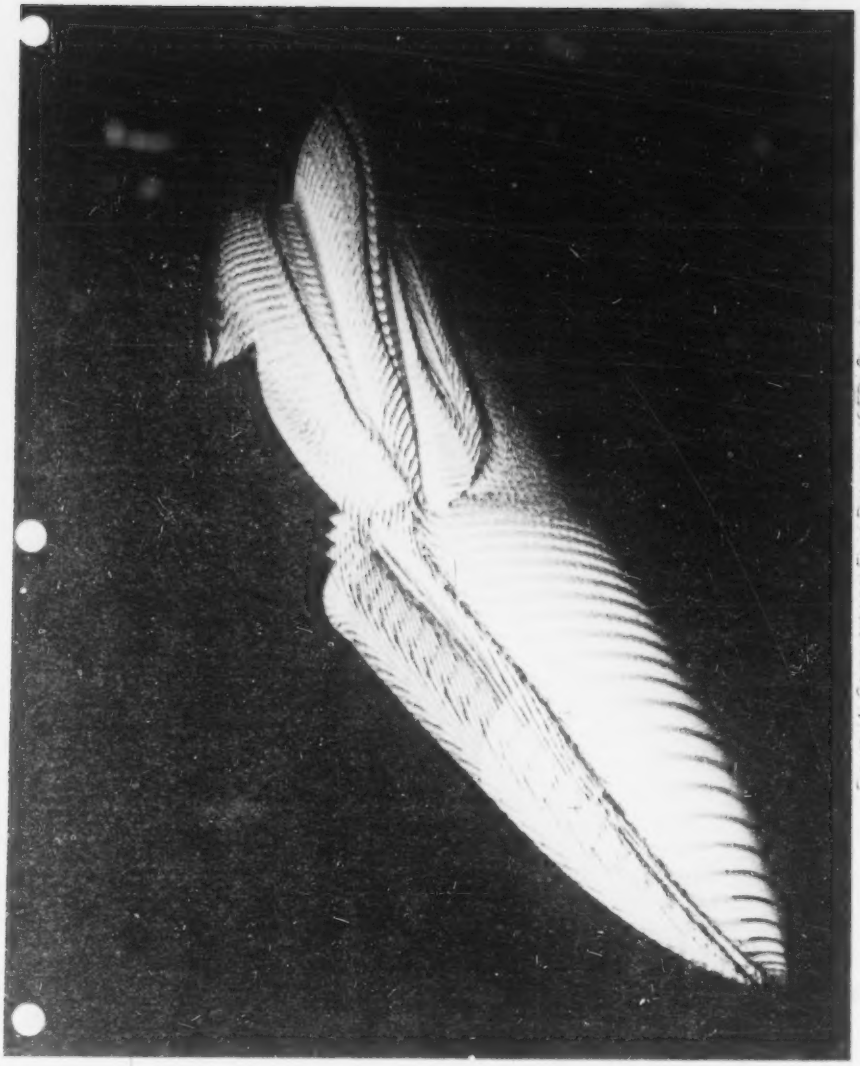


Figure 4. Computational Fluid Dynamics (CFD) Simulation
of Streamlines Showing Flow Patterns

Figure (5) F-18 High Alpha Research Vehicle (HARV) with Oil Streaklines Showing Surface Flow Patterns

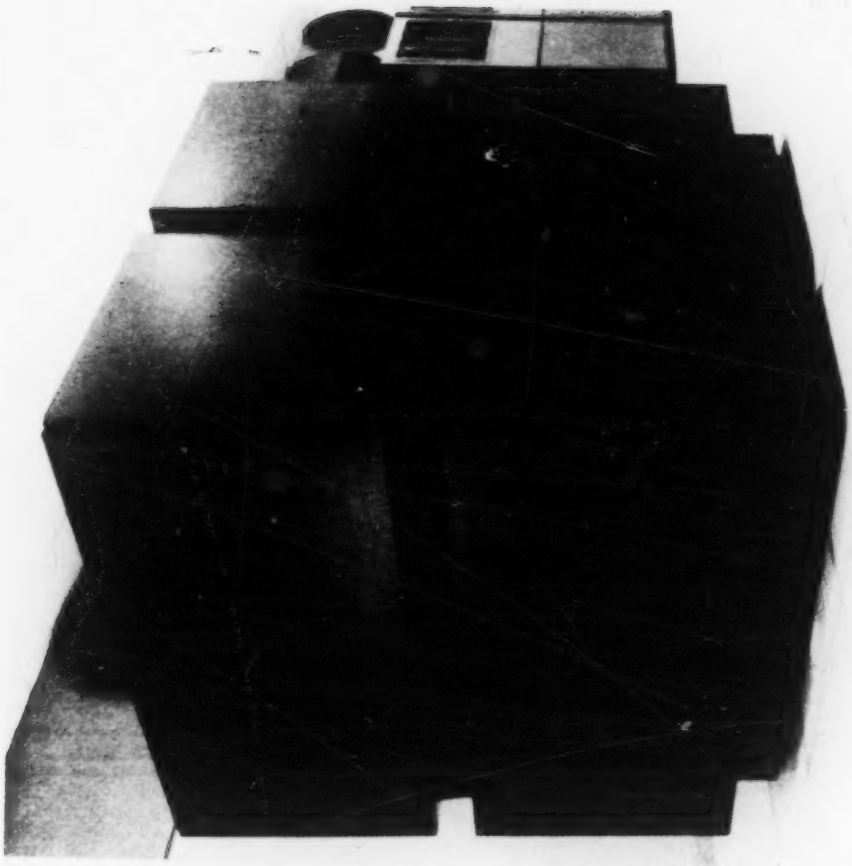


Figure (6) Massively Parallel Processing Research
Computer (Connection II Machine)

Figure (7) Takeoff Performance Monitoring System (TOPMS) Cockpit Display

FIGURE 8. HEAVY ROLL TEST FACILITY AT LANGLEY RESEARCH CENTER

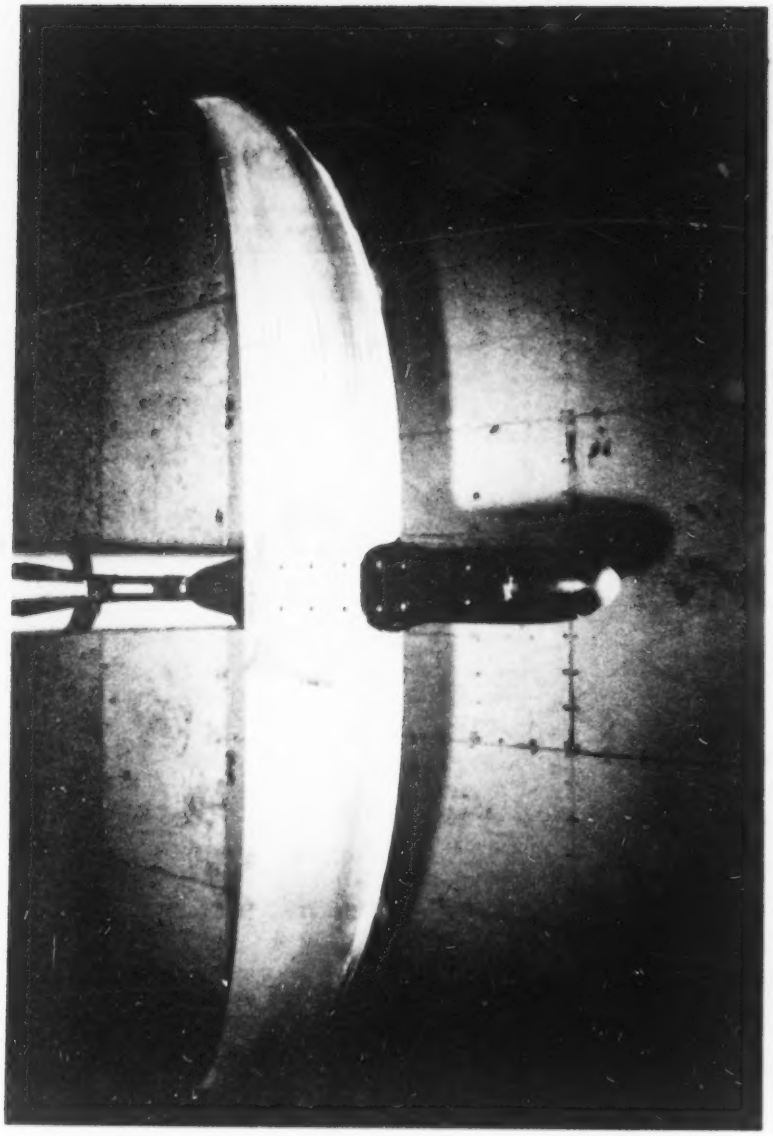
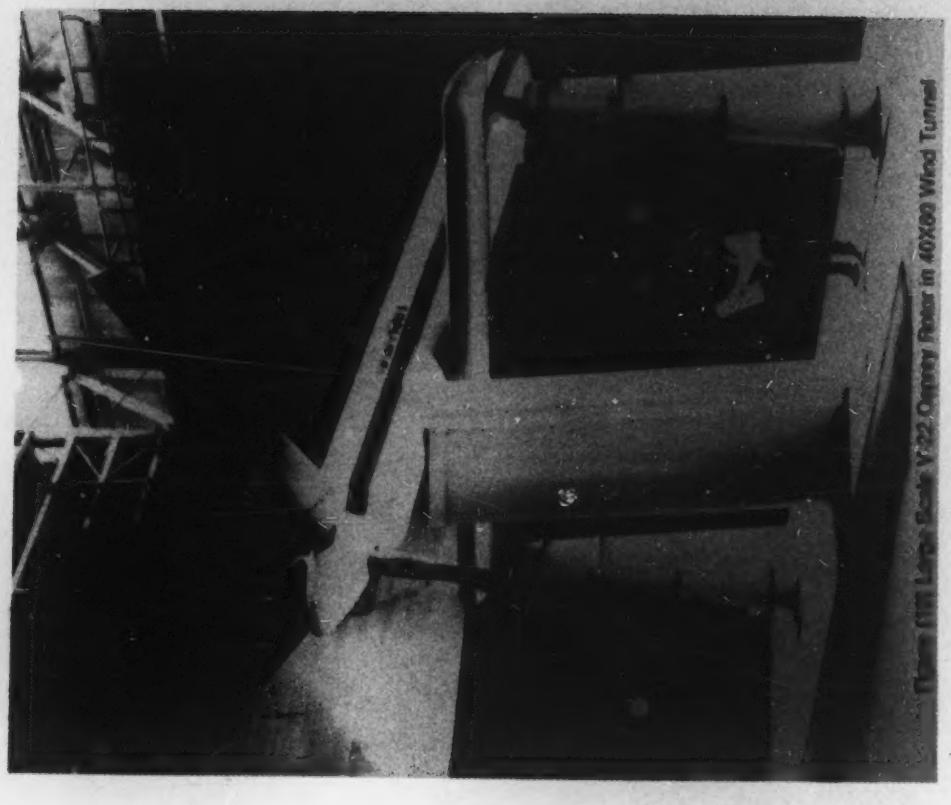


Figure (9) Model of Crescent Wing Concept in Wind Tunnel



Three-Fifth Large-Scale V-22 Osprey Rotor in 40X80 Wind Tunnel

Figure (11) Computational Fluid Dynamic (CFD) Model of
Delta Wing with Vectored Thrust in Ground Effect

Figure (12) E-7 V/STOL Model in 40X80 Wind Tunnel

Figure (13) 1988 Collier Trophy Awarded NASA/Industry Team

Mr. VALENTINE. Our next witness is Norris Krone, who is with the American Institute of Aeronautics and Astronautics.

Dr. Krone, welcome. We have your prepared statement, and it will be inserted in the record. And you may summarize it or otherwise proceed as you deem appropriate. We are glad to have you back here, sir.

STATEMENT OF NORRIS KRONE AMERICAN INSTITUTE OF AERONAUTICS ANDASTRONAUTICS

Dr. KRONE. Thank you very much.

On behalf of the American Institute of Aeronautics and Astronautics, we appreciate the invitation to come and express our opinion and maybe a perspective on the NASA aeronautics budget.

I represent, as the chairman of the aeronautics committee of the American Institute of Aeronautics and Astronautics, a broad cross-section, I think, of industry, academia, as well as the Government, and the opinions that I express here are those of the institute, not necessarily mine, but generally speaking they certainly fall in line with mine.

And I will start off by saying that I listened to Dr. Ballhaus' testimony and I couldn't find anything in it that I would disagree with. So, what I will do is give a perspective again of what our committee thinks of that budget.

In that regard, I would like to say that the NASP program and the B-22 cancellation occurred before we had our committee meetings, but we do have, if you had an opportunity to read the testimony, written testimony, we do have reference to it, and I will comment on that.

The last few years, we have been expressing at these hearings our concern with the Government's level of commitment to aeronautics in the NASA and the aeronautics program. Things are better this year, but we are still concerned. The emphasis this year, when we reviewed it earlier, was on the new initiative of the high-speed civil transport, and we examined that rather thoroughly.

I will briefly describe our perspective of that program as well as others in the NASA program and how we believe that initiatives should be logically reviewed relative to the total NASA aeronautics program and especially with regard to the environmental issues that are being raised relative to the high-speed civil transport and that are the focus of the NASA 1990 high-speed civil transport initiative.

Our perspective is that the high-speed transport is a natural product of technology advancement in aeronautics and aeronautical sciences, related sciences, just as the 600-mile-an-hour jet transport was to the 300- mile-an-hour prop airplanes that they replaced in the 1960s.

A decision to initiate a detailed design and construction of a prototype HSCT will be based on considerations of total costs, including the development cost, operation of the fleet, as well as an estimate of the passenger market and the tolerance for potentially higher ticket price to those passengers.

The environmental issues, which are sonic boom, airport noise, and the ozone depletion, are viewed as inputs to the design require-

ments of the aircraft and have the effect of making the performance objectives—speed, range and payload—harder to attain. I think it is important to recognize that when we talk about environmental issues.

But they definitely should be viewed as constraints just as, for example, material temperature allowables are constraints. We don't have the option of going out to 5000 degrees with materials that go into the engine, the engines of aircraft. If we did, we would have a lot more economical aircraft.

So, these environmental issues really are constraints. NASA's efforts to better define and understand the phenomenon is a proper and necessary step in the process, and we vigorously support the better definition of those constraints—in other words, just what the environmental issues are—because the unknowns involved there, I think, are the biggest impediment of all. It will undoubtedly have a larger influence on the total cost and, therefore, the decision to proceed with the prototype of the HSCT development.

Now, we believe these environmental issues should be viewed not as barriers but as hurdles that may be overcome and will definitely in the future be overcome. We think it is important to realize that the advance in overall technology base will lower the total cost of the fleet in its operations and it is only a matter of time before the cost and the economics of the market reach critical mass and a decision to initiate a prototype program will be reached.

The technology challenge is to create a practical design whose economics meet the market requirements. Now, a decision to proceed with a prototype of an HSCT will be based on technical and analytic judgments, but judgments that most certainly will involve elements of uncertainty. And it is not necessarily true that our judgment will be the same as our competitors'. It is not unreasonable to assume that at some point our competitors may feel more positive than we do and proceed with a design that could turn out to be a practical design of such an airplane. So, I think we ought to keep that in mind.

And now turning to the NASA 1990 aeronautics program, which includes the high-speed transport initiative, although there has been increase in the aeronautics budget in 1990, as you mentioned at the outset it is still approximately only seven percent of the NASA budget.

In other words, that is only seven percent as high as the others. And we don't believe that the proposed program is commensurate with the important challenge, challenges that face us in the future.

The key to winning in international competition for an economical, viable HSCT is—or subsonic, advanced subsonic aircraft or any other class of aircraft is a strong technology base and a design ingenuity that goes with it.

Meeting the environmental hurdles means increased support, financial support for aeronautics propulsion and materials.

These technologies can provide design solutions, and I think this is another aspect of our perspective, the increase in the level of technology is a design solution that can compensate for the environmental problems. They are effectively economic enhancers.

Now, looking at the NASA budget as we did in committee, the aeronautics side of it, the aerodynamics side of it, one of the key

technologies, when we looked at it, we see that it runs about 32 percent of the aeronautics budget, as it did in '89, even though there has been an increase in total aeronautics budget.

As it has been mentioned, it has been increased, but the aerodynamics, which includes fluid mechanics and numerical simulation, is about the same. On the structural and materials, it has dropped from 17 down to 15 percent. Propulsion is about the same as it was. We urgently would recommend substantially strengthening these three areas.

Now, the national aerospace program in relation to the budget itself and the high-speed transport, the high- speed transport is aimed at a relatively near-term benefit, whereas the NASP program has far-term benefits. Both are needed, but the NASP efforts are not a substitute for the work needed to produce a practical high-speed transport.

Bear in mind this before the announcement of the DOD elimination or almost elimination of the NASP program. The technology challenges to the NASP program is to demonstrate the feasibility of the hypersonic concept that involves substantially different technologies than those of the high-speed transport or a rotorcraft or subsonic aircraft.

We strongly support the NASP hypersonic effort, the part of the NASP program. This program should be continued regardless of the DOD budget cuts, we believe. We support a stronger NASA rotorcraft effort and the continued development of the tilt rotor technology.

We firmly oppose the termination of the V-22 development program, since the prototype aircraft can set the stage for follow-on civil versions. And with almost $3 billion or so spent on that program, it would be ill-advised not to finish the development.

In conclusion, we strongly recommend the support of the NASA 1990 aeronautics budget and endorse the stronger HSCT initiative and an increase in the two technology disciplines of aerodynamic structures, materials, and propulsion.

In addition, we strongly recommend support for the V-22, as I mentioned, in completion of its development program and the continuation of the NASP hypersonics program.

Incidentally, on the V-22, I understand from a study that the potential civil market is on the order of $20 billion for a civil version of that type of an aircraft.

Failure to meet these challenges can lead to a very large economic forfeiture as well as the loss of our leading position in the world of civil aeronautics industry. With a projected world market of over $550 billion in the next ten years, we must make the necessary investments to continue in our position of leadership.

Simply stated, the way to stay ahead is to run faster, and if we don't run faster, our competitors will surely pass us.

I would be happy to answer any questions you may have.

Mr. VALENTINE. Thank you, Dr. Krone.

We have a vote, and we will have some questions. And so, if you would, please stay with us. We will get back to you just as soon as we can.

Dr. KRONE. Yes, sir. I would be most happy to.

[Recess.]

Mr. VALENTINE. Dr. Krone, in your opinion, what are the—realistically speaking—what are the chances for eventual commercialization of the tilt rotor technology now that the military has cancelled the V-22?

Dr. KRONE. Let me say at the outset in answer to that question that what they have cancelled is both the development program, the completion of the development R&D program, which I understand is about $400 million, and the initial production phase of the V-22 production.

I strongly believe that it is a monumental mistake to cancel the completion of the development part of the program, since we have spent so much in the development of that concept.

The first tilt rotor, incidentally, crashed, unfortunately, in Texas in 1956, the first attempt at a tilt rotor. So, Dr. Ballhaus mentioned the four decades. Well, we actually lost one in a flight test not long ago, and we have been involved in the development of that concept ever since.

And I was the director of the vehicle technology at DARPA, and at that time I was looking at various vertical-takeoff technologies and the tilt rotor, I know, was very promising, and it has come to this point. So, there is a tremendous investment.

It is only a matter of time until the technology involved catches up to a commercial demand similar to the high-speed commercial transport situation. And I think with the V-22, it represents the first real practical application which would have been military services, which is appropriate because you don't have to meet all of the demands of the commercial market when you are fulfilling a military mission, obviously.

So, I think first of all the cancellation of the development stage is just unthinkable as far as a decision is concerned, and it would be very unfortunate not to have the experience of an operational vehicle to lead a commercial program.

Mr. VALENTINE. What is the situation overseas, Doctor, with respect to development of the tilt rotor airplane?

Dr. KRONE. As Dr. Ballhaus said—he knows as much about it probably and stated as much of that as I know. I think that we are—I would agree with him that we are ahead of the Europeans or far ahead of others in that regard.

And I think our lead, if we continue the development of the V-22 and go through some more or less operational tests program, that it would serve to give us the confidence that would be invaluable to our industry for continuing into a commercial program. The Europeans just don't have anything like that.

Mr. VALENTINE. But if our program is crippled, if we stop it, then we run the risk of yielding that frontier, development of that frontier to them, don't we?

Dr. KRONE. Well, we do. It is unknown as to exactly what they would do about it or how closely they follow our development.

I would presume, from my own personal experience in dealing with and having some contact with the aeronautical people in countries of our allies, that they follow our R&D efforts meticulously, much more so, I think, than we do theirs. So, they probably have a pretty darned good appreciation of what is in the V-22.

Mr. VALENTINE. What about the aerospace plane? If that program is sidetracked, so to say, is there a developed technology overseas that is capable of continuing with that?

Dr. KRONE. I believe so, sir. I will not repeat what Dr. Ballhaus said about the foreign development in that regard.

But I will add this, that the concept for either a one-stage or a two-stage payload to space vehicle is enormous there, and that is fundamentally because of the fact that you don't have to carry your oxidizer along with you if you use the atmospheric oxygen, which it does, and the fact that that has tremendous implications for the ratio of payload to initial takeoff weight of the vehicle.

So, I don't think that there is any question about the fact that at least for that application our competitors will proceed probably with much greater vigor if they see that our competition is less.

From the standpoint of the military application, they probably would have been the first that would have come out of it.

I think that the development of some sort of a vehicle, whether it meets the time schedule lines of the NASP program as established by the DOD or not, is an absolutely essential element of our aeronautics program.

In other words, far better in this case to slip than to cut. In other words, it is a technology program. So, if the technology is ready for initiation of a NASP vehicle by 1991, as currently scheduled, or 1993, I am not sure that there is that much difference in reality. But we should have something established and proceed towards it. In other words, if we have to take a funding cut, let's slip it, not cut it.

Mr. VALENTINE. Directing your attention to the high-speed civil transport, is it necessary to have a military precursor to the high-speed civil transport? And if so, is there one on the horizon?

Dr. KRONE. I don't think there is one on the horizon. I hadn't really thought of that. It would always be nice to have a military precursor because that assumes that you don't have to have all of the necessary economic benefits clearly defined, which are very difficult, which is a very difficult thing to do.

But in any case, I think that whether there is a military precursor or not, that is the program or that is a vehicle that will be developed. And our committee, our AIAA committee, firmly felt that way. And it is only a matter of time until this balance more or less or the crossing of the economic value versus the technology to bring the cost down cross.

Mr. VALENTINE. Do you think NASA's high-speed research program is sufficient to allow industry to begin development of this vehicle?

Dr. KRONE. Yes, sir. The entire program that goes out, I think something like ten years and, as I recall, over a billion dollars is right on as far as developing the technology base for it.

I believe that that program should proceed along with the environmental issue questions and not wait until the environmental issues are satisfied to the most stringent critics. In other words, we are really never going to have all of the answers to the ozone depletion, in my opinion, but we can design an airplane that knowing certain things about the ozone depletion, could be compatible with that problem.

And so therefore, I think that the development of the aeronautics, the basic aeronautical sciences, give us a tool with which we can develop an airplane that can satisfy those constraints.

Mr. VALENTINE. Is NASA's investment in aeronautical research adequate to keep pace with foreign competition, in your opinion?

Dr. KRONE. Well, in my opinion, it is not.

Mr. VALENTINE. What level would you think would be required in percentages of increase, perhaps?

Dr. KRONE. I chaired a workshop for the American Institute of Aeronautics and Astronautics a couple of years ago, and we talked at that time of the need to increase the budget as it was then by a factor of 50 percent within the next three years, as I recall the result of that committee. And I think that would be appropriate, and realistic incidentally. And that is with regard to inflation; in other words, a real growth of about 50 percent in the following three years, and we have not done anything like that.

And I don't think that it would be unreasonable at all to expect a 50 percent increase in the next couple of years. I believe that the country would gain from that sort of an investment far more in future aeronautics, both sales commercially and from the standpoint of the potential military benefit and security to the country.

I think the $460-some billion that is in the base R&T budget this year is really in real terms a pretty small number when you look at the cost of one airplane in today's dollars. So, we are investing less for the entire NASA aeronautics program than some of our current airplanes cost for one copy.

So, therefore, I think it not unreasonable at all or not pie-in-the-skying it, as it were, to say that a 50 percent increase would be appropriate. Granted, the budget concerns that we have today make that quite difficult.

Mr. VALENTINE. Mr. Rohrabacher?

Mr. ROHRABACHER. I will make this real quick.

Dr. Krone, let's change positions here for a moment. You are the congressman and you've got to make a decision.

Dr. KRONE. Yes, sir.

Mr. ROHRABACHER. You've got to make a decision on funding for continuing our tilt wing technology, our National Aerospace Plane, or development of a high-speed civil air transport.

How would you—what order would you put those in? If you're going to have to cut one, cut two, which is the last one you would cut, which is the first one you would cut?

Dr. KRONE. Since I am here representing the AIAA, that is a question that I couldn't answer very comfortably.

Mr. ROHRABACHER. Congressmen cannot answer very comfortably either, I can tell you that much.

Dr. KRONE. I understand that.

I would say that they offer different reasons, and I guess, from the standpoint of the value to the country, they are all very important programs. If I were a congressman, the true answer to that would be I would be looking at some of the other programs.

Mr. ROHRABACHER. I know. The programs that are produced in other people's districts. I know about those programs. But you cannot venture a guess for me? Frankly, I would appreciate your

guidance on this, sir. Someday I can call you on the phone if you want to do it off the record, but I think—

Dr. KRONE. I would much prefer to do it off the record, and I would be happy to answer the question as an individual citizen. But I would rather not answer it as a representative of the AIAA.

Mr. ROHRABACHER. That's fair.

Mr. VALENTINE. Send him an unsigned letter.

Dr. KRONE. I will put a big X.

Mr. ROHRABACHER. Thank you very much. And I appreciate it. I will not go into great detail. It's getting late.

When we talk about the other subject, I would also like to get your impressions on the high-speed civil transport, some of the reasons why and how it is different from the supersonic transport that they have overseas in Europe and et cetera.

Dr. KRONE. This is a personal feeling on it. I feel very strongly on that subject. My wife just came back from Tokyo, and so I know what she went through getting over there and back.

I personally feel that our technology level is reaching a point where the economics of a high-speed supersonic transport are rapidly approaching and if not the Japanese then some other country—

Mr. ROHRABACHER. They already have. They have the SST. It is going.

Dr. KRONE. The Concorde—

Mr. ROHRABACHER. They circle the world and lost their tail, and I don't know if the people who financed it lost their tail but I know the airplane did.

Mr. VALENTINE. Buckly.

Mr. ROHRABACHER. Part of the tail came off.

Dr. KRONE. The Concorde, you know, that is not the airplane, obviously. That is an old technology and it is a money-losing venture. And I don't mean money-losing from the standpoint of the tickets paying for the cost of operating the airplane today, but if you go back and look at the total cost to the British of developing and building that airplane. I think financially they would agree that they had not done the right thing. I think they have gotten a lot of good publicity out of it and today it is used extensively.

Mr. ROHRABACHER. Couldn't the National Aerospace Plane basically serve perhaps—aren't we looking for that same role to be serviced by the National Aerospace Plane eventually?

Dr. KRONE. As I mentioned in the testimony, the national aerospace plane is a totally different type of a program than what is projected as the high-speed transport, for this reason: that program is looking at the feasibility and a flight regime that is totally unexplored. As Dr. Ballhaus stated, that technology went dormant about 15 years ago and was revived by the national aerospace plane program and, incidentally, by my old agency and, incidentally, by my office when I was with the Department of Defense.

But what is being attempted there is to lay the groundwork much like, I guess is an analogy, the X-1 did for supersonic flight. The X-1 was not a commercial vehicle in any way, but it established the unknown concerning supersonic flight, which allowed for the military supersonic fighters and even bombers that followed.

So, the technology involved in the NASP program are truly cutting-edge. There are things that we do not know that they can be done. So, once that cutting-edge technology is established, then we can proceed on. That is going to take years, literally. It will be into, obviously, I think, past the next century before anyone seriously considers an operational vehicle, at least before one can be flying in a prototype stage.

On the other side, the high-speed supersonic transport program is aimed at establishing certain practicalities. There is no question, there is no question that we could build one today. We could have built one last year. The only question is is it economic, is it economically viable? Now that question has in it not only environmental and technology issues but it also has the economic unknown and that economic unknown is what the market is going to be.

Studies have shown that there is a strong market for it. The cost of the ticket, for example, in my opinion, the ticket on a high-speed supersonic transport to reach the Pacific Rim is like having a better product and people are willing to pay for a better product. You can get to Japan from the West Coast in three hours instead of 11 or 12, you know. If you can, then you are willing to pay for that. But this is an opinion of mine. And I don't think it is a true, logical way of looking at it to say that a premium on the ticket would be for only the rich businessman. I think there are a lot of people that travel that would pay, and rightfully so.

Mr. ROHRABACHER. Why isn't the Concorde slipped into this?

Dr. KRONE. As I understand, it is doing very well economically, economically at this point. In other words, the tickets cost more and they are filling the airplanes. And they cost more than even a first-class ticket on a subsonic airplane.

And when you look at the Concorde range, which is barely enough to reach across the Atlantic, the number of hours that they are saving the people and the productivity of the increased velocity and decreased time is not nearly as much as it would be for today's advanced supersonic transport that could reach Japan from the United States.

Mr. ROHRABACHER. I will be interested in talking with you off the record sometime seriously about that in terms of your priority in terms of the issues that we have to make unfortunate decisions about. It is unfortunate that you have to choose between two or three very good defensible programs, not only defensible but things that we think are vital. So, I would be interested.

Dr. KRONE. I would be most happy to.

Mr. ROHRABACHER. Thank you, Mr. Chairman.

Mr. VALENTINE. It is kind of like parents choosing between children. It really does come down to something similar to that. In this situation, almost everybody who has an interest in a program, you know, can make not just in areas that we are concerned with here, research, technology, science, space, but in all of these other areas where the Government has responsibilities. Everybody can make a case for the fact that if you don't do this, the world will collapse.

I just hope and pray that somehow we are able to make the right decision. So much is at stake here, and the repercussions of bad decisions made by leaders will saddle us with problems into the generations into the future.

But that is one reason that we have staff: to be sure that we don't make any bad decisions of all kinds and flavors.

Dr. KRONE. I will make one comment. I fly a light airplane, and I didn't mention that, but NASA's aeronautics business I think is vital to helping with the revitalization of the private airplanes flying in this country too.

Mr. VALENTINE. Thank you very much, Dr. Krone.

We thank all of the witnesses for being with us and others who came and to this hearing.

Dr. KRONE. Thank you very much.

If there is no further business, we will stand adjourned.

[Whereupon, at 4:00 p.m., the subcommittee was adjourned.]

[The prepared statement of Dr. Krone follows:]

AIAA American Institute of Aeronautics and Astronautics

Lay-in #2
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STATEMENT TO

SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES

BY

DR. NORRIS KRONE

AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

APRIL 26, 1989

370 L'Enfant Promenade, S.W. ■ Washington, D.C. 20024-2518 ■ Phone: (202) 646-7400 ■ FAX: (202) 646-7508

INTRODUCTION

Mr. Chairman and members of the Subcommittee:

The American Institute of Aeronautics and Astronautics (AIAA) is a non-profit professional society dedicated to advancing the arts, sciences and technology of aeronautics and astronautics and to promoting the professionalism of those engaged in these pursuits. We have a membership of over 43,000 drawn from all levels of American industry, academia, private research organizations, and government as well as from numerous nations abroad. I chair the Institute's Advisory Committee on National Aeronautics, whose members occupy positions of leadership in all segments of the aerospace community. The committee met recently to prepare recommendations for this testimony, and their names are listed at the end of this statement.

NATIONAL COMMITMENT TO AERONAUTICS

For the last few years the AIAA has expressed its concern with the government's commitment to programs that maintain U.S. dominance in aeronautics. Although government resources allocated to the development of aeronautical technology have been considerable, the resource levels allocated to NASA are not commensurate with either the enormous free world aeronautics market of the future, estimated to be upwards of $550 billion dollars over the next ten years, or with the needs of national security in maintaining a clear lead in military aircraft performance.

We are pleased, however, to note that there appears to be increasing recognition of these problems. The "National Aeronautical R&D Goals" published by the Office of Science and Technology Policy (OSTP) in 1985 and its 1987 sequel are direct evidence of this recognition. We wholeheartedly endorse these stated goals and the accompanying revitalization strategy. National security is dependent on maintianing superior aerospace products, and the viability of the industrial base for military aerospace products depends to a large degree on the commercial base.

The U.S. aerospace industry employs a large work force (approximately 1.3 million) and enjoys a large favorable balance of trade in the world marketplace. But the aerospace industry will suffer the same fate as our shipbuilding industry did after World War II if we don't work to maintain our technology advantage, which is key to U.S. superiority in future products, maintenance of national security and the economic benefits that derive from leadership in world sales of aeronautical products.

Hence we are concerned, despite the 1988 U.S. aerospace balance of trade estimates of a record $18.7 billion. Although our exports have grown since 1983 from approximately $15.3 billion to $22.75 billion (in constant 1982 dollars--a 49 percent increase), during the same period of time our imports grew from approximately $3.3 billion to $7.7 billion--a huge 133 percent increase. The ratio of imports to exports since 1983 grew from 15 percent to 34 percent. Moreover, this adverse trend occurred during a period of a weakening dollar. Significant elements in this growth of imports were foreign sales in civil helicopters

and general aviation.

The key to maintaining our world leadership position in aeronautics, both in the near-term and in the long-term, is research and technology. Our current technology lead, which includes the fuel-efficient propfan subsonic aircraft (a direct result of a NASA program initiated several years ago) scheduled to enter service in the early nineties, gives us an estimated three to five year advantage. But this advantage will erode if our current level of aeronautical R&D support is not maintained and strengthened. Support of advanced aeronautical technology, especially supersonic (near-term) and hypersonic programs (long-term), is a critical ingredient in maintaining the health of the aerospace industry.

NASA FY90 AERONAUTICS PROGRAM

General

Although the increased FY90 budget reflects a growing recognition of the importance of aeronautical research and technology to the health of the country, it is not sufficient for adequate development of U.S. aeronautics. Of the total $13.275 billion requested for NASA in FY90, only $860.0 million (less than 6.5 percent) is allocated for aeronautics, of which only $462.8 million is for basic research and development activities. Even with the $127 million programmed for the National Aerospace Plane (NASP), aeronautics is only 7.2 percent of the total NASA budget.

Although NASA does a good job of managing the available resources, there are too many critically important technical

areas to cover. Funds are spread alarmingly thin over many areas. As the technology becomes more and more sophisticated, hardware and software become more complex, and the resources needed to make significant advances increase proportionately.

ADVANCED HIGH-SPEED CIVIL TRANSPORT

Prospective

The AIAA strongly endorses the NASA high-speed research effort in aeronautics. Worldwide pressure for the development of an economically viable high-speed transport over the next few years is growing rapidly. If the U.S. does not make a vigorous commitment to pursue this objective we could forfeit considerable economic potential and lose our present leading position in the world's civil aviation industry.

An advanced high-speed civil transport (HSCT) is a logical product of technological advancement in aeronautical and system-related sciences. The decision to initiate the detailed design and construction of a prototype high-speed civil transport (HCST) will be based on consideration of the total cost--development, acquisition, and operation of the fleet--as well as of the passenger market and ticket costs.

Environmental considerations are a key factor in the overall design requirements of the aircraft. They will have a large influence on the total program cost and, therefore, on the final decision to proceed with HSCT development. Advancing the technology base will lower the total cost of the fleet, and it is only a matter of time before those costs and the economics of the market reach a "critical mass" and prompt a decision to

initiate a prototype design. We emphasize that this decision, while based on technical and analytical judgments, will involve elements of uncertainty as well.

Our judgment is not necessarily the same as that of our competitors, and it is not unreasonable to assume that they may feel more positively than we do. The Japanese are already looking for partners to join them in a development program.

The technological challenge is to create a practical design whose economics meet the market requirements. This is completely different from the National Aerospace Plane Program (NASP), in which the technological challenge is to demonstrate feasibility of a concept. The technology emphases of these two efforts are very different. HSCT activities are aimed at the near term, whereas the NASP program benefits will accrue in the far term.

Technology Program - The 1990 NASA high-speed research program oriented toward the critical environmental issues is not commensurate with the importance of the challenge. The keys to winning the international competition for an economically viable HSCT are the technology base and the design ingenuity that can be brought to bear. The sonic boom, airport noise and ozone depletion must be addressed, and NASA is correct in conducting research and analysis in these important areas. These considerations will produce design constraints on the aircraft, but they should not be viewed as barriers--hurdles to be overcome would be a better description. Overcoming them, however, will require increased effort and funding support in the associated technologies, primarily aerodynamics, propulsion, and materials. These technologies can provide design solutions for the

environmental problems while enhancing the economic viability of the aircraft.

THE NATIONAL AEROSPACE PLANE (NASP)

Hypersonic Technology - The NASP program represents the revitalization of 1965-75 hypersonic research efforts. Hypersonic technology has now reached the point at which actions directed at the definition of a hypersonic research vehicle are both credible and promising.

Propulsion is key to the development of a useful aerospace plane. NASA's Langley Research Center program in the Hypersonic Research Engine (HRE) demonstrated the basic feasbility of building an engine that could operate at Mach numbers beyond 5, and it led to the important conclusion that the only practical concept for a hypersonic airbreathing vehicle would be an integrated airframe/engine design. A scaled module of such a hydrogen- burning propulsion unit was built and tested to Mach 7 at Langley, laying the foundation for the propulsion concept that made the aerospace plane program possible.

A practical aerospace plane must have low structural weight. The high temperature environment and enormous heat transfer capability required present a unique set of problems and challenges beyond those of subsonic or supersonic vehicles. Recent advances in high-temperature metals and metal matrix materials, advanced carbon-carbon and ceramics, structural designs for regeneratively-cooled techniques, and advanced insulated cryogenic tank designs imply practical and economic hypersonic vehicle designs.

Military vehicle effectiveness is measured by the ability to defeat a projected enemy threat. Commercial vehicle effectiveness is measured by the ability to compete economically with other vehicles that can meet the projected customer need. Hypersonic air-breathing vehicles could meet both military and commercial requirements, but the military benefits are likely to be realized sooner.

An advanced Space Transportation System (STS) is a potential use of the technology being developed for NASP. The hypersonic transport aircraft application, because it must meet more stringent safety and economic constraints, is probably a longer-term prospect which will depend on the experience gained from earlier military or STS applications.

TECHNOLOGY BASE PROGRAMS

We are pleased to see the overall increased funding for the technology-base programs, but we remain convinced that NASA's aeronautics program should give stronger emphasis to fundamental aeronautical technology. National aeronautical goals cannot be met without a strong and vigorous technology-base program. The NASA program needs particular strengthening in:

- Aerodynamics, including fluid mechanics and the verification and correlation of computational aerodynamics codes
- Advanced structures and materials (metals and composites)
- Propulsion and power R&T
- Unique rotorcraft technologies.

Aerodynamics and Fluid Mechanics

The NASA Aeronautics Directorate recommended a budget

increase of $7 million (26 percent) in fluid and thermal physics activities. The applied aerodynamics budget increase is $9.5 million (15 percent), and the numerical aerodynamics budget increase is $1.5 million (4 percent). These three line items totalled $131.8 million (32 percent) of the FY 89 Aeronautics R&T and Systems Technology budget and they account for $149.8 million (still 32 percent) of the FY 1990 Aeronautics R&T Systems Technology budget. That is, there has been no relative growth. These three line items support the energetic and active pursuit by NASA of computational fluid dynamics (CFD) and its verification by wind tunnel testing. NASA has led the world in CFD development, which is applicable to a wide range of commercial and military aircraft, and in innovative boundary layer, high angle of attack, and wing planform research. These basic research efforts have produced a significant return on investment in both commercial and national security terms. Taken together, they are one of the three highest priority programs in the total aeronautics budget, and therefore should be considered for further funding increases.

The NASA Aeronautics Directorate recommended a budget increase of $4.5 million (1 percent) for FY 1990 relative to FY 1989 in materials and structures research and technology. In systems technology, the budget increase is $1.2 million (4 percent). These two line items accounted for $69.2 million (17 percent) of the 1989 Aeronautics R&T and Systems Technology budget, and are projected to account for $70.8 million (15 percent) of the FY 1990 budget estimate, reflecting a decrease relative to other R&T and Systems Technology line items.

These technologies provide for the characterization of advanced materials properties (metallic, intermetallic, ceramic, polymer and composite) and the application of these advanced materials to primary aircraft structures. NASA's involvement in the materials arena is highly beneficial to the aerospace community at large; it is similar to the NASA CFD initiative in that the data base is available to all U.S. industry. Lightweight, durable, cost-effective aircraft structures are central to U.S. military and civil goals in aeronautics, so these two line items taken together are one of the highest-priority programs in the total NASA aeronautics budget. They are therefore recommended for further funding increases.

Propulsion and Power - Advanced propulsion systems technology for 1990 is budgeted at the same level as in 1989. Although NASA has made excellent progress in developing advanced turboprop propulsion technology (the propfan), we are concerned that the budget allocated to general aviation/commuter engine technology is quite small. Since NASA is the only primary source of technology for general aviation manufacturers, this technology program demands substantial growth.

Rotorcraft Technology - NASA should continue to focus on improving rotor efficiency over a wide flight envelope and on reducing noise and vibration levels. Improved ability to define and control the downwash and wing download will also lead to more effective systems for both civil and military applications. We believe that NASA should not have a significant role in the transition of the V-22 tilt-rotor vehicle into the civil sector;

however, the agency should still play an important part in improving tilt-rotor and conventional helicopter performance and environmental acceptability. With the relatively low funding level allocated for this technology, emphasis should be on developing the fundamental analytical tools and on addressing problems generic to all rotorcraft.

Supersonic Short Takeoff and Vertical Landing (STOVL) Technology:

The ability to accomplish short takeoff and vertical landing with a supersonic fighter is an obvious military goal. Achievement of that goal depends on reducing or eliminating the weight and drag penalties associated with vertical takeoff and landing. If and when that goal is accomplished, STOVL mission needs can be more accurately defined.

The NASA STOVL technology programs center on maturing propulsion-system technology. The US/UK ASTOVL Executive Steering Committee recently narrowed the criteria for propulsion-system concepts, which should receive emphasis in the NASA technology program. Several of the key technologies other than the propulsion system include Integrated Flight Propulsion Controls (IFPC), ground effects, hot-gas ingestion, high-temperature structures, and aerodynamic/propulsion-system interactions.

Manufacturing Technology: NASA should be involved in aircraft manufacturing technology only to the extent needed to characterize the properties of new materials and structural concepts. A database on new materials that show promise for aerospace applications would be extremely useful to industry. Design allowables, fatigue strength, and changes in properties

following exposure to a wide variety of chemicals should all be documented as functions of temperature and time at temperature. Suitability of the materials for basic manufacturing processes should also be determined; i.e., can a given material be drilled, molded, or extruded? Explaining new structural concepts using computerized optimization codes has the potential for significant weight savings. However, application-oriented manufacturing technology is best left to the aircraft manufacturers and the military services, which have the technical experience and financial orientation needed to exercise good judgment in developing the "factory of the future."

NASA FACILITIES AND STAFFING

NASA has historically provided unique national research facilities. Despite increased support in FY 89, there remain large deficiencies in NASA wind-tunnel facilities, both in large-scale, low-speed facilities and in high-speed facilities applicable to the hypersonic regime. Some of this deficiency is compensated for by computation (numerical aerodynamic simulation) which, although useful, is both expensive and limited in availability and is still subject to verification by flight-test and wind-tunnel data. New European large-scale low-speed wind tunnels are modern and efficient, bringing competitive advantages to European developments such as the new Airbus models.

Besides new facilities for both ground and flight testing, NASA needs to develop the new generation of engineers and scientists that will create tomorrow's breakthroughs. NASA must encourage the imaginative, creative, analytical people who will

forge new material and structural concepts and new propulsion system approaches. They must exploit the unique NASA experimental facilities, which cannot be easily duplicated by industry or universities, to expand our aeronautical capabilities. We therefore recommend an increase in the NASA engineering budget allocations for facilities and education.

CONCLUSION

The AIAA vigorously supports the proposed increases in the NASA FY 1990 aeronautics budget, especially the strong effort to lay the technology groundwork for an advanced supersonic transport aircraft. We particularly endorse stronger efforts in the aerodynamics, materials, and propulsion technology areas which can close the economic gap between subsonic and supersonic flight. We also recommend increases in the NASA technical staff, and improvements in NASA wind tunnels.

The aeronautics industry is critically important to the nation's security and economic well-being. The future health of that industry is directly related to the investment we make in today's aeronautical technology programs. With a projection of over 550 billion dollars in worldwide aircraft sales during the next ten years, it is essential that we make the necessary investments in technology development today. Past investments in that technology led to our current leadership position, and they will pay large dividends in the future. We therefore strongly support the increased FY90 funding level of NASA aeronautics technology, and look to a further increase in FY91.

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Dr. Norris Krone is the Executive Director of the University Research Foundation of the University of Maryland. He is responsible for directing all aspects of the Foundation's technical and program management activities. As a previous Director of the Air Vehicle Technology Office of the Defense Advanced Research Projects Agency, he was directly responsible for major innovations of aeronautical and tactical technology. While at DARPA, Dr. Krone developed and verified technical principles that made possible the forward swept wing aircraft concept; he then initiated and managed the X-29 flight demonstrator program. For these efforts, Aviation Week recognized him as a major contributor to the Aeronautical Sciences and, most recently, the American Institute of Aeronautics and Astronautics honored him with its Aircraft Design Award for an original concept that led to a significant advance in aircraft design and technology. Dr. Krone was also responsible for many developments in the STOL Technology area, including the X-Wing Aircraft, Tactical Cruise Missile Development, and Reconnaissance Systems involving aircraft and sensors.

Dr. Krone received a Ph.D. in aeronautical engineering from the University of Maryland, a Masters Degree from the Air Force Institute of Technology, and is a graduate of the Air Force Command Staff College. He served as a fighter pilot in the Air Defense Command of the Air Force and is a veteran of over 200 combat missions as a forward air controller during the war in Vietnam. Dr. Krone has flown over twenty different kinds of aircraft, which include nearly all existing types. He is a member of the Aerospace Safety Advisory Committee, and is the chairman of the AIAA's National Aeronautics Advisory Committee.